Amendments

In accordance with 37 CFR §1.121, please amend the above-identified application as set forth below.

Amendments to the Specification:

Please insert the two (2) replacement paragraphs below for the first two (2) paragraphs on page 1.

This application is a continuation-in-part of U.S. Application No. 10/283,421, filed on October 29, 2002 and issued as U.S. Patent No. 6,719,547 on April 13, 2004, which is a continuation-in-part of U.S. Application No. 10/013,747, filed on October 19, 2001 and issued as U.S. Patent No. 6,599,112 on July 29, 2003.

This application is also related to the subject matter in co-pending U.S. Application No. 10/283,422, filed on October 29, 2002 and issued as U.S. Patent No. 6,719,548 on April 13, 2004, which is hereby incorporated by reference into the present invention disclosure. This application is also related to the subject matter in co-pending U.S. Application No. 10/764,195, patent application filed on January 23, 2004, Docket No. 71044-006CIPN2, which is also a continuation of U.S. Application No. 10/283,421 and is also hereby incorporated by reference into the present invention disclosure.

Please insert the replacement paragraph below for the last paragraph beginning on page 4.

Leak pathways are generally ~~cause~~caused by internal leakage between the rotors and the housing and between the rotors themselves and result in volumetric losses and thermodynamic losses due to recirculation of the working fluid within the rotors. For example, working fluid that

is pressurized and leaks into a lower pressure region of the rotors is caused to expand to the lower pressure state with a higher temperature due to entropy and then must recirculate through the rotors before being expelled. Therefore, the overall temperature of entire rotor system, including the rotors and the working fluid, is increased due to the gain in entropy. Internal leakage is detected specifically at the following points:

Please insert the replacement paragraph below for the last full paragraph on page 6.

Until now, screw rotor expanders, compressors and pumps have had similar fundamental flaws. Generally, they allow for leak pathways between the working side, i.e., expansion, compression or pumping, to the side that should be sealed from the working side for proper operation of the rotors, i.e., non-working. These rotor designs are commonly referred to as Roots-type rotors and Lysholm-type rotors. Krigar-type rotors, which are described in German Patent Nos. DE 4121 and DE 7116 from more than a century ago, have fallen out of favor, and this may possibly be due to the rise of the Lysholm-type rotors in the 1930's and 1940's. In an article entitled "A New Rotary Compressor" and written by Lysholm in the 1940's, Lysholm puts down the Krigar design as being unable to obtain any compression between the lobes with a two-thread/two-groove design (2x2 configuration). While it is clear from the images of the Krigar design that there definitely were sealing issues, especially between the threads and the grooves, and Krigar appears to be more directed to radial flow, the Lysholm conclusion that the Krigar design could not perform any compression with only the 2x2 configuration is flawed.

Regardless, the industry and teachings have generally followed Lysholm and ~~roots~~Roots with very little interest given to Krigar, except as a historical reference.

Please insert the replacement paragraph below for Equation No. 1 on page 16.

$$\text{Arc Angle } \beta \quad \geq \quad \text{\sout{N}}M * \text{Arc Angle } \alpha, \quad M \geq 1 \quad (1)$$

Please insert the replacement paragraph below for the last full paragraph on page 19.

The screw rotor device 10 illustrated in Figure 7A also incorporates the phase-offset relationship into its design. The angle between ray segment oa and ray segment ob, subtending tooth 42, is arc angle α. According to the phase-offset definition provided above, arc angle β of the toothless sector 46 extends from ray segment ob to ray segment oa', which would correspond to ~~some~~the multiplier (M) and arc angle α.

Please insert the replacement paragraph below for the last paragraph beginning on page 25.

It will be appreciated that the gap 90 in the embodiment illustrated in Figure 3A and discussed above is within a sealing tolerance that is within an order of magnitude of the distance between the top land of the thread and the bottom land of the groove. It will also be appreciated that the gap 90 in the embodiment illustrated in Figure 10D is even smaller than that in Figure 3A and that the gap can be completely eliminated by designing the cusp of the housing to be exactly at the point where the thread intersects the groove, such as discussed in detail below with regard to the thread and groove sealing at one or both cusps (SR-6 and SR-7). Accordingly, there

is no leak pathway or stream-tube to show in the present invention. However, the leak pathways are already well defined in the art and understood by those skilled in the art. For example, the leak pathways are discussed in detail in U.S. Patent No. 5,533,887, which is hereby incorporated by reference.

Please insert the following replacement paragraphs below for the paragraphs beginning with the last paragraph on page 26 through the last paragraph on page 29, inclusive.

To show the sealing relationships of the present invention, Figure 10C uses the symbols A, B and C~~FS~~ to refer to the front side sealing of the screw rotor and A', B' and C'~~BS~~ to refer to the back side sealing of the screw rotor. It will be appreciated that the top and bottom of the screw rotor are relative to its positioning and are merely used for simplicity of reference in relationship with the drawing. Generally, according to the direction of travel shown in Figures 10A and 10B, the top portions are the trailing portions and the bottom portions are the leading portions. Of course, if the direction of the rotors is reversed, the top portions would then be the leading portions and the bottom portions would then be the trailing portions. Also, Figure 10C uses ~~the bracket symbols "{" and "}" are used with~~ alpha-numeric reference codes and other symbols to particularly identify the following Sealing Regions (SR), which may also be referred to as sealing relationships:

SR-1: ⇧ (CC') - top land seals with bottom land (1st SR)

SR-2: A/CB - trailing ridge seals, at least partially, along trailing face (2nd SR)

SR-3: AC - trailing edge seals with trailing side (3rd SR)

SR-4: A'/C'B' - leading face seals with leading ridge (4th SR)

SR-5: A'C' - leading edge seals with leading side (5th SR)

SR-6/SR-7: ⊙ - triple seal between ridge, edge and cusp, A-front (6th SR) & A'-back

(7th SR)

SR-8: =‖ - major diameter of female rotor seals with cylindrical bore (8th SR)

SR-9: ‖= - top land seals with cylindrical bore (9th SR)

SR-10: /‖\ - female rotor major diameter seals with male rotor minor diameter (10th SR),

including the seal between the groove's ridge and the thread's root portion, ✕ B-top &

✕ B'-bottom

SR-11/SR-12: ‖| - housing ends seal with respective ends of rotor (11th SR & 12th SR)

As summarized in the listing above and particularly illustrated in Figure 10C, the sealing

relationships are described in detail below. The first sealing relationship SR-1 has a center,

intermeshing sealing area defined by the geometries of the top land and the bottom land. The

second sealing relationship SR-2 has a front, outer sealing line defined by geometries of the

trailing face and the trailing ridge. The third sealing relationship SR-3 has a front, inner sealing

line defined by geometries of the trailing edge and the trailing side. The fourth sealing

relationship SR-4 has a back, outer sealing line defined by geometries of the leading face and the

leading ridge. The fifth sealing relationship SR-5 has a back, inner sealing line defined by

geometries of the leading edge and the leading side. The front, outer sealing line and the front,

inner sealing line define boundaries of a front, intermeshing sealing area between the trailing face

and the trailing side and intersect at a common front sealing point according to the sixth sealing

relationship SR-6 defined by intersection of trailing edge, trailing ridge and front cusp. The

back, outer sealing line and the back, inner sealing line define boundaries of a back, intermeshing

sealing area between the leading face and the leading side and intersect at a common back sealing

point according to the seventh sealing relationship SR-7 defined by intersection of leading edge,

leading ridge and back cusp. The eighth sealing relationship SR-8 has a first peripheral sealing

area defined by geometries of female rotor major diameter and the cylindrical bores. The ninth

sealing relationship SR-9 has a second peripheral sealing area defined by geometries of the top

land and the cylindrical bores. The tenth sealing relationship SR-10 has a center, non-meshing

sealing area defined by geometries of the female rotor major diameter and the male rotor minor

diameter, and includes the seal between the groove's ridge and the thread's root portion. As with

most screw rotor compressors, the ends of the female rotor and the male rotor are in a sealing

relationship with the ends of the housing, i.e., the eleventh sealing relationship SR-11 and twelfth

sealing relationship SR-12. It will be appreciated that a number of these sealing regions are

sealing areas while others may be sealing lines, depending on the particular selection of design

variables for the rotors, discussed below.

The creation and progression of these seals, as the male and female rotors intermesh, is

illustrated in Figures 11A-11H. These illustrations show a series of cross-sectional views of the

screw rotor device, and the particular sealing regions are shown and described with reference

thereto. Even before the thread 36 and the groove 38 begin sealing, there is a seal between the

female rotor's major diameter and the male rotor's minor diameter. On the front side of the

screw rotors 14, 16, the top of thread 124 begins sealing the top of the groove 114 right at the

front cusp 130 and, as the rotors continue to intermesh, continues sealing along the top of the groove for the entire length from the female rotor's major diameter to its minor diameters (points A and C respectively illustrated on Figure 10A). On the back side of the screw rotors, the bottom of the groove 112 begins sealing the bottom of the thread 122 at its root 134 (point B illustrated on Figure 10a), and, as the rotors continue to intermesh, continues to seal more of the root until the bottom of the thread starts sealing along the bottom of the groove and ultimately seals along the entire bottom of the groove from the female rotor's minor diameter to its major diameter (points A' and C' respectively illustrated on Figure 10A). Intermediate points lining the top and bottom of the grooves also respectively seal with intermediate points lining the top and bottom of the threads. The bottom of the groove completes the seal of the bottom of the groove at the back cusp 132.

As discussed in detail below, with regard to the illustrations in Figures 14-16 and 17, all of these seals can be designed into the family of screw rotors according to the present invention, and by incorporating all of these seals into a screw rotor system, all of the leaks discussed above, including the blow-hole gap can be simultaneously reduced to within specified tolerances, also discussed above. With the buttress-thread rotor designs (see Figures 7A and 7B), the blow-hole gap can still be eliminated, but the complete seal is limited to a single-pitch because, with multiple-pitch rotors, a gap 134 exists between the trailing side of the groove and the trailing face of the thread (see Figure 13E) which could cause significant leakage from the high pressure side of the screw rotor system to the low pressure or suction side of the screw rotor system.

According to the designs of the other non-buttress thread embodiments of the present invention, the gap between the trailing side of the groove and the trailing face of the thread does not exist, even when the screw rotors are multiple-pitch designs. Generally speaking, the buttress thread designs have a single-sided sealing relationship, i.e. between the leading side 112 of the groove 38 and the leading face 122side of the thread 36face, whereas the other designs have a double-sided sealing relationship between the leading side 112 of the groove 38 and the leading face 122side of the thread 36face and between the trailing side 114 of the groove 38 and the trailing face 124side of the thread 36face. The double-sided sealing relationship can be particularly defined by the first sealing relationship SR-1, the second sealing relationship SR-2, the third sealing relationship SR-3, the fourth sealing relationship SR-4, and the fifth sealing relationship SR-5. In this way, no leak pathway is provided through this double-sided sealing relationship. An illustration of this double-sided sealing 136 is particularly shown for multiple-pitch rotors 138, 140 in Figure 10B. In particular, there is a leading axial seal 142 between the leading face of the thread and the leading side of the groove and a trailing axial seal 144 between the trailing face of the thread and the trailing side of the groove, and these sealing regions can be sealing areas. For compressor applications, the leading face/leading side seal may be more important than the trailing face/trailing side seal because the trailing face seal meets with and "disappears" into the end seal as the compression stroke is completed (see Figure 10B). However, the trailing face/trailing side seal can be especially useful if it is desired to maintain a pre-compression of the working fluid, i.e., even before the thread seals with the groove.

Please insert the replacement paragraph below for the last paragraph beginning on page 31.

Figures 15+7 and 16+8 illustrate other thread and groove designs that can form entire families of screw rotor profiles. Figure 15+7 takes the groove's trailing line and leading line from Figure 14+6 and turns them into a thread's leading line and trailing line, i.e. reversing them, to show that the same design process can be used in reverse and will result in groove sides that are a reverse of the groove sides in Figure 14+6. Figure 16+8 shows in phantom lines the groove's leading line and trailing line from the initial stage of the design, i.e. before using the intermediate points lining the groove's bottom side 3'" and top side 4'" respectively to define intermediate points lining the thread's bottom face 3" and top face 4". After performing this final step, the solid lines show that the thread's leading lines and trailing lines, i.e. respectively corresponding with the groove's leading lines and trailing lines, become more arcuate. However, for machining purposes, it is still possible to change the design to a set of straight line segments, or even other arcuate sections, while still remaining within the design tolerances for the particular application and family of rotors. Figure 16+8 also shows how families of curves can also be based on different minor diameters of the male and female rotors, even when the major diameters remain constant.

Please insert the replacement paragraph below for the last paragraph beginning on page 35.

An example of an application that cools the working fluid is illustrated in Figure 18, in which one screw rotor device 10 operates as a compressor 154 for the incoming working fluid and the other screw rotor device 10 operates as an expander 156. After exiting the outlet port of

the compressor, the working fluid is preferably~~preferable~~ passed through a fluid conduit 158 to an intercooler 160 or other type of thermodynamic processor, such as a heat exchanger, and then the working fluid enters the expander through its inlet section. The working fluid may also be selectively recirculated by a control valve 162~~160~~ through ~~the expander, and in this~~a recirculation path 164~~process, the working fluid may be passed through another heat exchanger~~. Additionally, the compressor and expander can be mechanically linked through a drive shaft 166, which could also include gears.